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Cloud characteristics and cloud attenuation over Kolkata

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Abstract The cloud occurs for higher percentage of time than rains so its effects in relation to the deterioration of signals in the radio systems can not be ignored. In this paper, cloud statistics over Kolkata for different months have been presented. The attenuation of radiowave due to clouds from 10 GHz to 100 GHz is more in winter season than the other seasons.

Keywords Cloud occurrences, cloud attenuation and cloud temperature

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1 Introduction

Radio communication systems specially designed with low power margins are affected by cloud [1]. If occurrence statistics of cloud and rain are known at the design stage of radio communication systems, then power requirement for tactical communications can be taken care of. Many workers [2–7] studied cloud and rain effects on microwave and millimeter waves in the past, over different parts of the world. But, the cloud-based studies in relation to the attenuation of radiowave due to cloud over Indian locations, have not been done in the past. This is the first time an attempt has been made for the Indian subcontinent.

The primary maxima of cloudiness are found between 30° and 60° north and south latitudes. In these latitudes in the temperate zones, there is preponderance of cyclones and fronts. In each hemisphere, there is one belt of minimum amount of cloudiness that coincides with the latitudes of subtropical anticyclones and trade winds. Within the subtropical high pressure belt, the cloudiness is less on continents than on the oceans. Because of the descending air currents in the subtropical belt, all the hot deserts of the world are located here. It is therefore, natural for cloudiness to reach its minimum in these regions marked by clear skies. Besides these, there are annual as well as diurnal variations in the amount of cloudines in a particular region [8]. In the equatorial region, there is little variation in amount of cloudiness from one month to other. But between 10°–20° North and South latitudes, the cloud maximum occurs during summer monsoon months. The western sides of continents within the subtropical belt have the cool season maxima of cloudiness as well as precipitation. In the higher latitudes, the continental interiors have a summer maximum of cloudiness, since winters are marked by anticyclonic conditions there. Daily variation of cloudiness is a function of the type of cloud present in the sky. In case of cumulus clouds, a maximum is reached in the early and middle afternoon. Stratus and other stratiform clouds show their maximum in the early morning.

It has been found that the cloud occurs for longer period on yearly average than the rain. Therefore, the study on the effects of clouds on radiowave in microwave and millimeterwave frequency bands during different months and time, is rather important over different locations in India. Some studies, on the statistics of the rain effects causing attenuation of radiowaves have already been done [9–11]. But the studies related to the attenuation due to cloud statistics are lacking over the Indian subcontinent.

In this study, an attempt has been made to deduce the statistics of cloud occurrences when the sky is covered wholly or partially over an Indian tropical station,

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Kolkata (22.32°N, 88.27°E) during different time of day and night for all the months. It has been found that during day time (0830, 1130, 1430, and 1730 Hrs IST) in the months of June, July, August and September, the sky is covered with cloud for a significant percentage of time (92% to 95%). While during night time, it has also been observed that in the month of June, July, August and September the sky is covered with clouds for a considerable percentage of time (73% to 88%) The attenuation due to cloud from 10 GHz to 100 GHz has also been deduced It is seen that the attenuation due to cloud is more in winter season than in other seasons.

2. Results and discussions

It has been reported that the density of water content in cloud varies from 0.15 g m $^{-3}$ to 1 g m $^{-3}$ and its concentration varies from 70% per cm^{3} to 40% per cm^{3} [3]. The average diameter of cloud particles, reported by Slobin [3] varies from 9 μm to 30 μm while raindrops have size distribution of 100 μm to 5 mm The cloud is not water vapour and relative humidity is 100% within the cloud. Cloud is also found at high temperature as well as low temperature of which high level clouds consist of ice particles. Ice particles have no effect on the microwave frequency of radiowave. The thickness of the cloud varies from 1.5 km to 2.5 km depending upon the type of the cloud Slobin [3] reported that for light cloud, the thickness is around 0.2 km while for medium cloud, the thickness is 0.5 km and for heavy cloud, the thickness is 1 km and 1.5 to 2 km.

The low cloud data obtained from the India Meteorological Department is used to deduce the cloud occurrence statistics. The data pertains to the period 1985 to 1990 The observations are at an interval of 3 Hrs in 24 Hrs. The night time observations are taken during 2030 Hrs IST, 2330 Hrs IST, 0230 Hrs IST and 0530 Hrs IST. The four observations on each day and night are good enough to be the representative conditions of day and night. The results on cloud statistics have been provided on monthly basis in this paper. The day time and night time average cloud statistics of a month are the true representative of the daily cloud statistics in that month.

The cloud cover is estimated by an observer visually and reported as the number oif eighths of the sky covered by clouds [12] (IMD, 2000) The cloud cover is estimated by the observer and expressed on a scale ranging from 0 to 8 Octas. Here 0 Octas means clear sky, 4 Octas means that one-half (or four-eighths) of the sky is covered with cloud and 8 Octas means fully covered (overcast).

The number of days the sky is covered wholly or partially with clouds during the different time in a day in each month is shown in Figure 1. It is seen in Figure 1 that in the month of June, July, August and September, the cloud occurrences are very significant (20–30 days). In the months of April, May, October and November, the cloud occurrences are moderate (15–20 days) while during the months of January, February, March and December, the cloudiness is less significant (5–10 days).

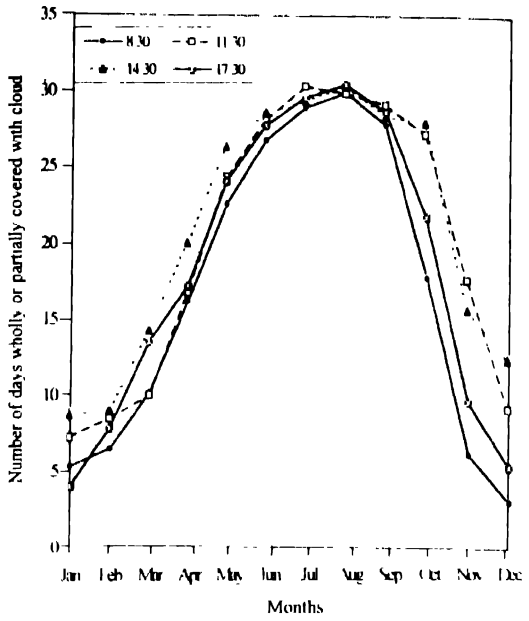

Figure 1. Number of days the sky is covered wholly or partially with cloud in different months during various time of observations in day time over Kolkata

Figure 2 shows the number of nights, the sky is covered wholly or partially with clouds during the different time in a night in each month. It has been observed from here that the June, July and August months are very significant (25–30 days) for the cloud occurrences while May and September months are also significant for 20–25 days

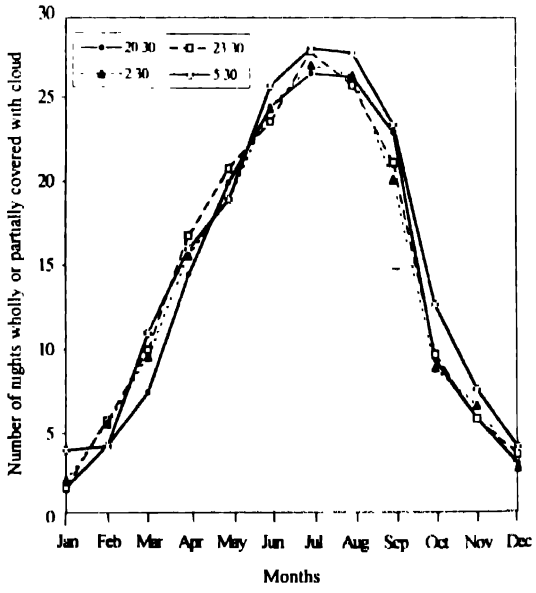

Figure 2. Number of nights the sky is covered wholly or partially with cloud in different months during various time of observations in night time over Kolkata

March, April and October months show moderate occurrences of cloudiness (10-20 days) and the months of January, February, November and December show very less cloudiness (2-10 days).

The trend of number of days of cloud occurrences wholly or partially during each month for all the four observations in a day are shown in Figure 3. It has been observed that

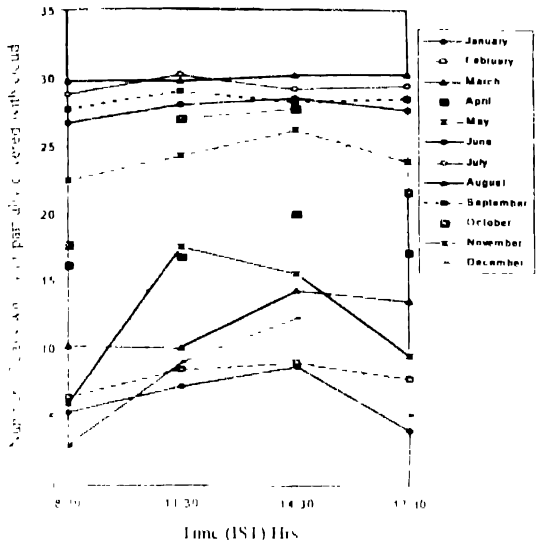

Figure 3. Diurnal variation in cloud observations during day time only in different months over Kolkata

the diurnal variation is not prominent in the months of June, July, August and September when the cloud occurrences are maximum. But in other months when the cloud occurrences are less, there is variation in occurrences in different time.

Figure 4 presents the cloud occurrences in different time during night in different months. It is seen that slight variations are there in occurrences of clouds in different time during the different months.

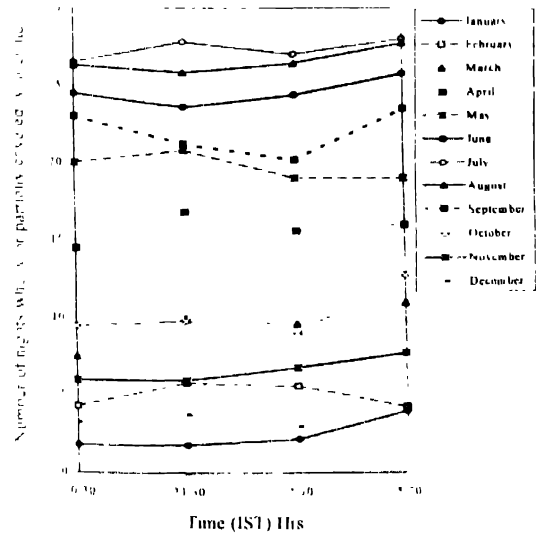

Figure 4. Diurnal variation in cloud observations during night time only in different months over Kolkata

The range of results on attenuation of radiowave due to cloud for different water particle density varying from 0.1 gm/m^3 to 1.0 gm/m^3 and at different frequencies and at 0°C isotherm height (273 K) which is assumed to be cloud temperature in this study, has been estimated by the following expression provided by Slovin [3] and Staelin [13].

$$\alpha = \frac{4.343 \times M \times 10^{0.0122(291-T)^{1.3}} \times 1.16}{\lambda^2} \text{ dB/km},$$

where α = Specific attenuation due to cloud (dB/km),

M = Cloud water particle density (g/m^3),

T = Cloud temperature (K),

λ = Wavelength of radiowave (cm).

Table 1. Specific attenuation of radiowave with varying cloud water particle densities

	Specific Attenuation (dB/km)				
Frequency (GHz)	M = 0.1 g m^{-3}	M = 0.3 g m^{-3}	M = 0.5 g m^{-3}	M = 0.75 g m^{-3}	M = 1.0 g m^{-3}
10	0.008	0.023	0.038	0.058	0.077
20	0.031	0.092	0.154	0.231	0.308
30	0.069	0.208	0.346	0.519	0.692
40	0.123	0.369	0.615	0.923	1.230
50	0.192	0.577	0.961	1.442	1.923
60	0.277	0.831	1.384	2.076	2.768
70	0.377	1.130	1.884	2.826	3.768
80	0.492	1.476	2.461	3.619	4.922
90	0.622	1.869	3.114	4.672	6.228
100	0.769	2.307	3.845	5.767	7.690

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